Online Biochemical Oxygen Demand Monitoring for Wastewater Process Control—Full-Scale Studies at Los Angeles Glendale Wastewater Plant, California

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ABSTRACT: The main objective of this investigation is to determine whether or not it would be feasible to use the measured values of biochemical oxygen demand (BOD) of wastewater obtained by an online instrument at the Los Angeles/Glendale Water Reclamation Plant (California) for controlling its activated sludge process. This investigation is part of a project to develop online BOD monitoring for process control in the City of Los Angeles wastewater treatment plants. Tests studied the Siepmann und Teutscher GmbH (ISCO-STIP Inc., Lincoln, Nebraska) BIOX-1010, which uses a bioreactor containing a culture of microbes from the wastewater to measure soluble BOD in 2 minutes. This rapid approximation to the operation of secondary treatment allows anticipation of system response. Calibration measurements allow the operators to find a conversion factor for the instrument's microprocessor to compute values of BOD that agree well with the standard 5-day BOD (BOD_5) measurement, despite the differences in the details of the two testing methods. This instrument has recently been used at other wastewater treatment plants, at a number of airports in Europe and the United States to monitor runway runoff, and is also being used on waste streams at an increasing number of food processing plants.

A comparison was made between the plant influent BOD values obtained by the BIOX-1010 online monitor from the end of August, 2000, to late January, 2001, and the individual and average values obtained for the same period using the standard BOD_5, 20°C test, to determine the effectiveness of the Biox-1010 to identify shock loads and their duration. Individual BOD estimates and averages over periods of overly high biological loads (shock loads) were compared, and the instrument readings were evaluated for their effectiveness in detecting shock loads. The results were highly satisfactory, so the instrument was used to trigger a shock-load warning alarm since late September, 2000. This allowed flow diversion and temporary storage to prevent process upsets. *Water Environ. Res.,* **80,** 298 (2008).

KEYWORDS: biochemical oxygen demand (BOD), activated sludge, online BOD monitoring, process control, shock loading, industrial waste, bioreactor, biomembrane.

doi:10.2175/106143007X184672

Introduction

This paper presents the results of testing the ISCO-STIP BIOX-1010, a bioreactor device for rapid estimation of biochemical oxygen demand (BOD) (ISCO-STIP Inc., Lincoln, Nebraska). The BOD is generally considered by plant operators to be the most important measure of wastewater strength, but the standard laboratory procedure to measure it, the 5-day BOD (BOD_5) test (APHA et al., 1992), has a number of deficiencies (Iranpour et al., 1998; Iranpour, Shao, Magallanes, and Flaig, 1997; Logan and Patnaik, 1997), as follows:

(1) At 5 days from sample collection to result, it is too slow for process control;
(2) It requires excessive time from laboratory personnel;
(3) It requires excessive numbers of incubator bottles and space in incubators;
(4) Its many dilutions increase the chance for error;
(5) It is not a close simulation of biological oxidation in a treatment plant; and
(6) It is not amenable for continuously monitoring variations in the BOD of wastewater influent entering the plant.

Rising standards for environmental protection make it desirable to monitor the BOD of primary influent fast enough to allow plant operation to adapt to influent changes, especially the rapid rises to excessive organic strength, known as *shock loads.* Appropriate manipulation of these loads, by either bypassing them to a lagoon or an equalization basin, prevents disruption of secondary treatment and violations of discharge standards.

Review of Literature. Faster tests for related parameters have been available for years, but are not fully satisfactory by current standards. The BOD_5 test is slow because it waits for the microbial population in the wastewater to metabolize most of the available substrates. Thus, methods that make faster BOD estimates measure oxygen use, while speeding up consumption of the substrates by providing additional biomass. This strategy was introduced more than 20 years ago (Leblanc, 1974). Automated fast respirometers are becoming more widely available, with units specialized for BOD estimation that work 1000 to 2000 times faster than the BOD_5 test.

The BIOX-1010 (Cosa Instrument Corporation, 1994) is a bioreactor respirometer that was developed in the 1980s. Riegler (1984, 1987) describes a slightly different earlier model, with results from tests on several types of wastewater. Köhne et al. (1986) also report work with this model. The manufacturer has made additional improvements in the instrument since the study reported here, including extending the range of instrument readings to 100 000 mg/L and providing instructions for freezing bioreactor contents to allow for resumption of service without a culture acclimation period, if

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a) Front view

b) Bioreactor

Figure 1—ISCO/STIP BIOX-1010 pictures: (a) front view, and (b) bioreactor.

a toxic event killed the bioreactor culture, or if there should be a period when the instrument was not needed. The instrument is finding increasing use in the United States and Europe, as shown by its use at wastewater treatment plants in Honolulu, Hawaii, and San Diego, California, and as a monitor for the waste streams at a number of dairy-product factories in Minnesota and Michigan. It is also used at the airports at Portland (Oregon), Denver (Colorado), Kansas City (Missouri), Dallas (Texas), New York (JFK), Washington D.C., London (Heathrow), and Frankfurt (Germany), to monitor wastes (mostly antifreeze compounds from deicing operations) in their runway runoff.

Substantial literature is available on the many instruments and measurement methods that have been introduced in the past 20 years (Anatel Corporation, 1996; Columbus Instruments, 1994; Central Kagaku Corporation, 1994; Harita et al., 1985; Hikuma et al., 1979; Iranpour and Flaig, 1995a, 1995b; Iranpour et al., 1998, 2000; Iranpour, Shao, Magallanes, and Flaig, 1997; Iranpour, Straub, and Jugo, 1997; Karube, Matsunaga, Mitsuda, and Suzuki, 1977; Karube, Matsunaga, and Suzuki, 1977; Karube, Mitsuda, Matsunaga, and Suzuki, 1977; Li and Zhang, 1996; Logan and Patnaik, 1997; Logan and Wagenseller, 1993; Loomis, 1991; Riedel, 1994; Strand and Carlson, 1984; Young and Cowan, 2004) and about the value of timely BOD monitoring (Belles and Lyons, 1991; Jarrel, 1991; Klopping, 1991; Manning, 1991).

Present Study. The results reported here were obtained at the Los Angeles/Glendale Water Reclamation Plant (LAG) (California), which was designed to process an average of 75 700 m^3/d (20 mgd) of wastewater and has been in operation since 1976. It is one of the inland ''upstream'' treatment plants in the Los Angeles network, built to reduce the flow that must be treated at the large Hyperion plant on the coast. In addition to domestic waste, approximately 30% of the LAG influent is industrial waste. The plant provides tertiary treatment, but has no sludge-processing facilities. Primary and waste activated sludge (WAS) are returned to the sewer for treatment at Hyperion.

The objectives of this study were the following:

(1) Determine the best point in the plant flow for installation of the instrument intake during the test,
(2) Compare the performance of the BIOX-1010 with the results of the standard laboratory BOD_5 measurement,
(3) Verify that shock loads would be detected timely and reliably,
(4) Test planned methods to respond to the shock loads, and
(5) Determine operations and maintenance requirements.

The paper also includes brief comparisons with other instruments and comments on the new capabilities provided by the instrument's speed.

Method

Structure and Operation. The BIOX-1010 is designed for operation in the field. Figure 1 shows photographs. The sample flow range is from 1 to 80 mL/min, the fresh water flow range is 5 to 500 mL/min, the reactor total mixed inflow and outflow is constant at 500 mL/min, and the operating temperature range is 27 to 32°C. The hydraulic loading range for flow in the bioreactor (primarily resulting from the recirculating pump) relative to the total area of the plastic carriers in the bioreactor is 590 to 2600 $m^3/m^3{\cdot}d$ (10 to 45 gpm/ft^2).

The BIOX-1010 more closely approximates both the BOD_5 test and the operation of the WAS process than any other fast respirometer of which we know. Like the BOD_5 test, it relies on the metabolism of the native microbial population of the wastewater to consume the dissolved oxygen (DO). It is like the WAS process in speeding up the consumption of the microbes' food by providing a larger mass of microorganisms than the ambient population used in the BOD_5 test. For municipal wastewater, the sample stream is all the seed culture that is needed. The acclimatization period is approximately 6 to 7 days and depends on the waste stream constituents and the rate of growth of the microorganisms.

The instrument's operation is based on Michaelis-Menten kinetics (Riegler, 1984, 1987). The operating conditions are maintained in the region where the Michaelis-Menten function makes the oxygen consumption rate essentially proportional, both to the food supply and the microbial population (that is, the mathematical departure from perfect proportionality is small, so that proportionality is assumed to hold within the accuracy of the measurements that are feasible under the operating conditions). The microbial population is held constant by using an immobilized biofilm on a collection of plastic carriers with a fixed total surface area, so that the oxygen consumption rate only depends on the food supply.

The instrument determines how much the sample must be diluted to maintain an approximately constant BOD concentration in the bioreactor. Measuring the operation of the pumps gives the microprocessor a dimensionless dilution factor that is converted to a BOD estimate by multiplying by a constant, L_k. This is the reading that would be obtained if no dilution were needed. Hence, it is set by the user to give the best available estimate of the BOD that is maintained in the reactor by the dilution. An initial L_k value is picked from a range of values given by the manufacturer, and the instrument is calibrated to pick a specific L_k value for the waste stream being monitored (here, the LAG treatment plant activated sludge process), to obtain BOD values that are comparable within reason to the values of BOD_5, 20°C. It should be noted that, in the application in this paper, the computed BOD values from the BIOX-1010 using an appropriate L_k value are used only for monitoring and controlling the BOD loads to the aeration tanks, and the BOD values computed are not intended for reporting National Pollutant Discharge Elimination System (NPDES) compliance or any other regulatory purposes.

The feedback in the measurement process protects the culture from any shock loads in the waste stream. On the other hand, the microbes are vulnerable to incoming toxic substances. Riegler (1984, 1987) describes operation in a toxicity-detecting mode. However, this mode is incompatible with BOD measurements, so this study did not use it.

The operating range 27 to 32°C for the BIOX evidently is higher than the 20°C of the standard BOD_5 test. The exponential dependence of the bacterial metabolic rate on the temperature in this range implies that, at approximately 30°C, only a few hours are required to obtain as much degradation of organic materials as what occurs in the 5 days of the BOD_5 test. Because biodegradation is much more rapid at 30°C than at 20°C, the few minutes of residence time in the instrument's bioreactor are equivalent to approximately 1 hour at 20°C (because the operating range is 27 to 32°C, the actual ratios differ significantly between the ends of this range). Thus, compounds with a somewhat wider range of degradability contribute to the instrument readings than appears to be the case when the temperature difference between the instrument and the BOD_5 test is not considered.

Calibration. The short-term accuracy of outputs depends on only three things—calibration of the pumps, accuracy of the dissolved oxygen probe output, and calibration factor L_k. Clearly, the pumps need to be in good mechanical condition. The electrochemical dissolved oxygen probe produces current proportional to the dissolved oxygen concentration in the surrounding water. It is protected from contact with the microbial population by a plastic membrane. In the instrument, a spray device cleans the membrane with fresh water, at intervals programmed by the user.

To determine L_k for the conditions of a particular application, it is necessary to start operation with some plausible L_k and then to correct it. A selected instrument output, based on that value of L_k, is recorded, and a sample for BOD_5 testing is obtained at the same time, from a faucet on the front of the BIOX that accesses the instrument's input stream. The manufacturer's procedure for correcting L_k from the BOD_5 results includes consistency and reliability verification features. Operation at LAG began with L_k = 5, but, after the test, L_k was reset to 2.5.

Over the longer term, the reliability of the output depends on the stability of the conditions under which the calibration was performed. Because, as noted above, the metabolic rate in the bioreactor is sensitive to temperature, a significant departure from the bioreactor temperature used at the time of the calibration would invalidate the determination of L_k. However, the flows of sample and dilution water through the instrument provide some help in stabilizing the temperature against daily fluctuations, and, as noted below, the instrument at LAG was installed in an air-conditioned shed, which obviously has a strong temperature-stabilizing effect on the instrument. It seems likely that seasonal changes in the temperatures of the water supplies will change the bioreactor temperature somewhat over several months, but, as noted below, the current maintenance schedule calls for monthly calibrations, which should be adequate to adapt to seasonal changes and can be done at a tolerable cost.

Reasonable stability of the composition of the wastes in the sample stream is another condition needed for reliable results from the instrument. This is clear because, even when one allows for the higher temperature in the bioreactor, the short residence time in the bioreactor evidently prevents degradation of the more slowly metabolizable organic compounds that contribute to the results of the BOD_5 test. Because the mix of residential and industrial users in the service area of a large wastewater treatment plant generally changes slowly, over the long term, one can expect considerable stability of the daily pattern of fluctuations of flow and composition at such a plant. Furthermore, in the absence of shock loads like those discussed below, the composition is generally stable enough over daily cycles that the calibration has not appeared to be significantly compromised. The results below show that shock loads were detected satisfactorily, so, even in such cases, the effect of composition changes has not departed excessively from the calibration.

Maintenance and Service. At the primary effluent, slime tends to build up quickly in the strainer and dissolved oxygen probe membrane surface. Experience at LAG calls for cleaning the strainer and the dissolved oxygen probe membrane surface for 1 hour once per week and calibration and cleaning of the pumps once per month. Since the beginning of November 2000, the actual interval between membrane and strainer cleaning has been more commonly 10 days or 2 weeks. Examination of long-term behavior suggests that the dissolved oxygen probe cap, which includes the membrane, needs to be replaced approximately every 2 months.

Setup and Startup. A shed was set up to shelter the BIOX-1010, with an air conditioner to maintain the temperature in the operating range 27 to 32°C. It was placed next to the end of tank number 8 and as near as possible to the primary effluent flow channel, so that the sample travel time would not greatly increase the total response time of the system, and to prevent changes in the sample BOD. Figure 2 is a plan view of the setup and a flow schematic of the instrument. A submersible pump inside the primary effluent channel pumps the sample from 1 m (3 ft) below the surface through a hose approximately 90 m (300 ft) long, for a transit time of approximately 5 minutes. The BIOX-1010 was installed August 5, 2000. Mixed liquor from the aeration tanks was transferred to the bioreactor, so the acclimatization period was just a few hours. From August 7, 2000, to August 16, 2000, the unit was being observed and evaluated for performance and maintenance dependency. The ranges of BOD readings were stable, with no large variations (the

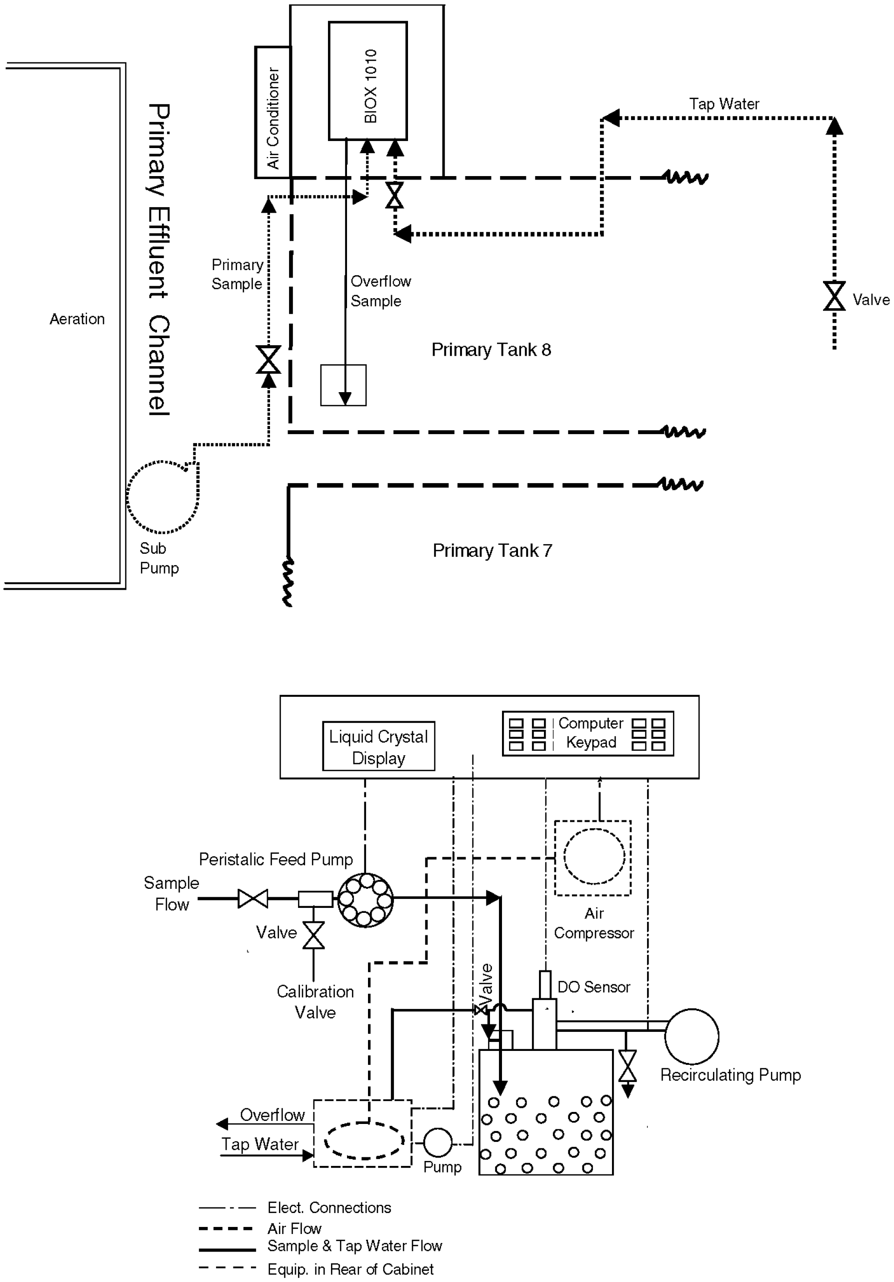

Figure 2—Flow schematic of BIOX-1010 at LAG.

ranges on the last 3 days were, respectively, 300 to 463 mg/L, 293 to 455 mg/L, and 270 to 437 mg/L), and the readings were maintained for more than 3 days without needing maintenance. It was decided that the unit had passed its startup test.

Figure 3 is a plot of the online BOD range of values before and after L_k calibration as a function of time, from August 20 to August 31. The first 3 days of this figure show that, when $L_k = 5$ was used, the online BOD readings were in the range 220 to 440 mg/L, with two brief excursions to lower values of approximately 120 mg/L. On August 23, the L_k factor was set at 2.5. After the new L_k factor was set, the online BOD readings were in the range 110 to 270 mg/L. Although the new L_k factor produced BOD values comparable to the range of BOD values determined by *Standard Methods* on composite samples of the influent collected at LAG over the years (APHA et al., 1992), the BOD still trended upward as a function of time, because of rapid bacterial growth on the surface of the dissolved oxygen probe membrane. Several manual cleanings were done, each of which greatly reduced the BOD readings for a short time. On August 29, the software was commanded to perform the self-cleaning spray on the dissolved oxygen probe membrane twice a day. Since then, the unit has operated well, and the variability in the BOD values computed by BIOX was not high.

Test Procedures. The samples for BOD_5 were collected with an autosampler set up on top of the primary effluent channel next to the submersible pump suction port, from which the samples are being withdrawn. The autosampler was programmed to collect

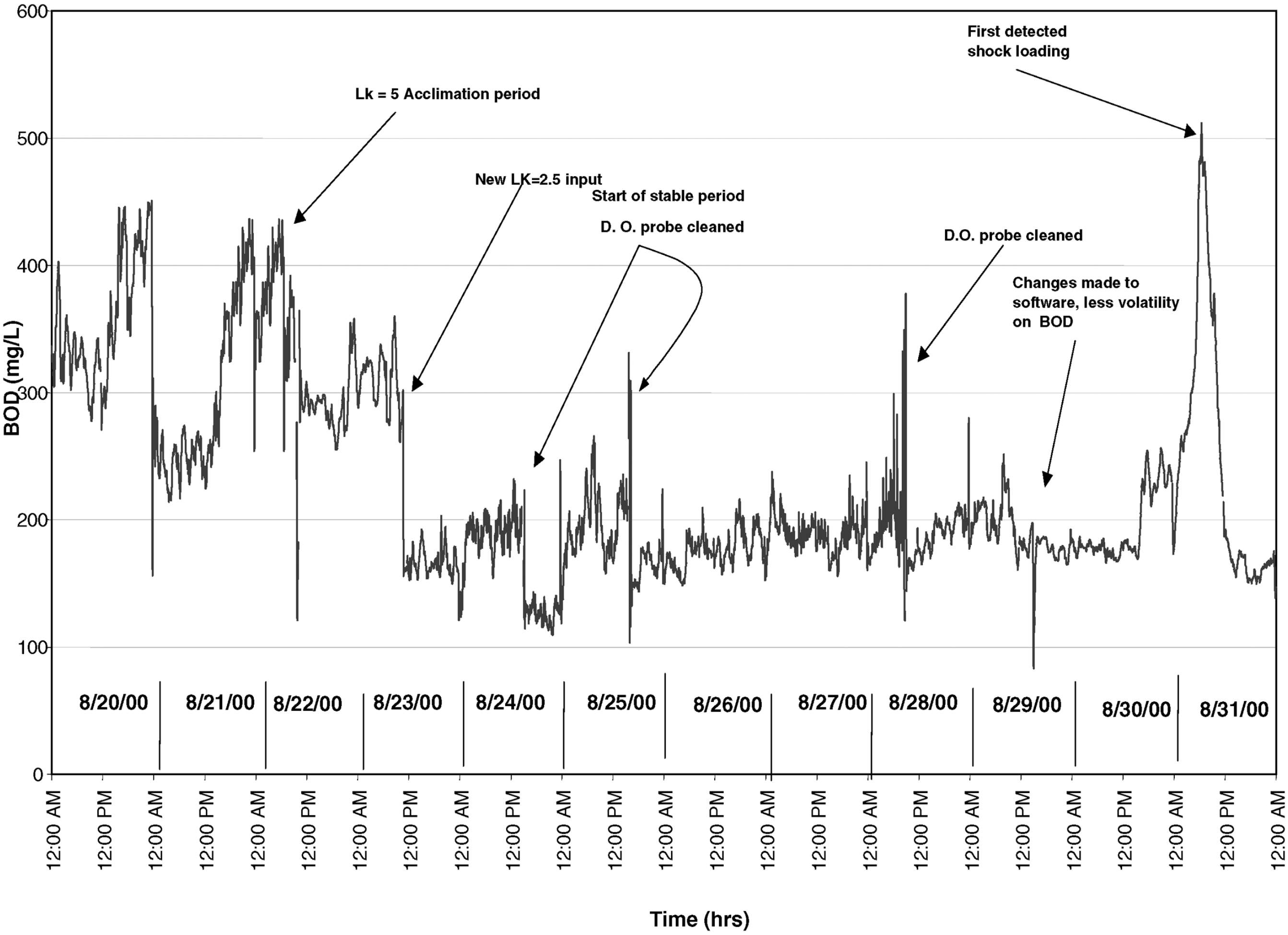

Figure 3—Online BOD trends before and after L_k calibration.

600 mL of primary effluent every 2 hours into 1-L containers, and microorganism activity was slowed by keeping the temperature low with ice placed in the middle section of the autosampler carousel. After the last sample was collected, the samples were delivered to the plant's laboratory for BOD_5 analysis. The first sampling series started at 12:00 a.m. on September 20 and ended at 10:00 a.m. on September 21. The second, third, fourth, and fifth sampling series were done on September 26 to 27, October 3 to 4, January 9 to 10, and January 17 to 18, respectively.

Observations, Results, and Analyses

Comparison with 5-Day Biochemical Oxygen Demand Tests. Although the test conditions differed under which the online BIOX-1010 and standard BOD_5 values were obtained, a comparison was nevertheless made to see whether these values compare well. If these compare well, regardless of the differences in test conditions and other theoretical aspects (i.e., the effect of seeding and temperature, batch nature of the standard BOD test, and particle density in the diluted suspensions), operators will have a tool in their arsenal to monitor and control a waste stream exerting a very high BOD before it enters into the aeration tanks. Figures 4a through 4e show the results from September and October, 2000, and January, 2001. The plots suggest that the instrument readings are generally less variable than the laboratory results, neither rising as high on the peaks nor sinking as low in the dips. In particular, during the shock-load event on September 26 and 27, 2000, as seen in Figure 4b, the peak BOD reported by the instrument was approximately 350 mg/L, while the peak BOD_5 was approximately 450 mg/L. Nevertheless, the closeness of the standard BOD_5 and online monitor test results can be seen from the above figures.

Detection of Shock Loads. There has been no difficulty in distinguishing between shock loads and the daily BOD rises that LAG often experiences during the transition of low flow to average flow in the morning, which occurs between 6:00 a.m. to 8:30 a.m., as seen in Figure 3. These brief normal rises last approximately 1 to 2 hours. The highest BOD value during the period of flow transition is approximately 230 mg/L. If the BOD value rises above 230 mg/L with a duration of 40 minutes or more and the aeration basin dissolved oxygen level decreases to the range 0.0 to 0.2 mg/L, then a shock load is considered to occur.

Figures 5a through 5l are time-series plots of the online BOD data. They show that, before and during a shock load, the BOD exertion can increase by as much as 100% or more for periods of 6 to 10 hours. For comparison, they also show a number of days of no shock loads, such as August 30 and September 1 (Figure 5a) and September 19 (Figure 5b). September 19 is a particularly good example of the normal BOD rises at approximately 6:00 a.m., and additional examples of daily flow histories are included in Figures

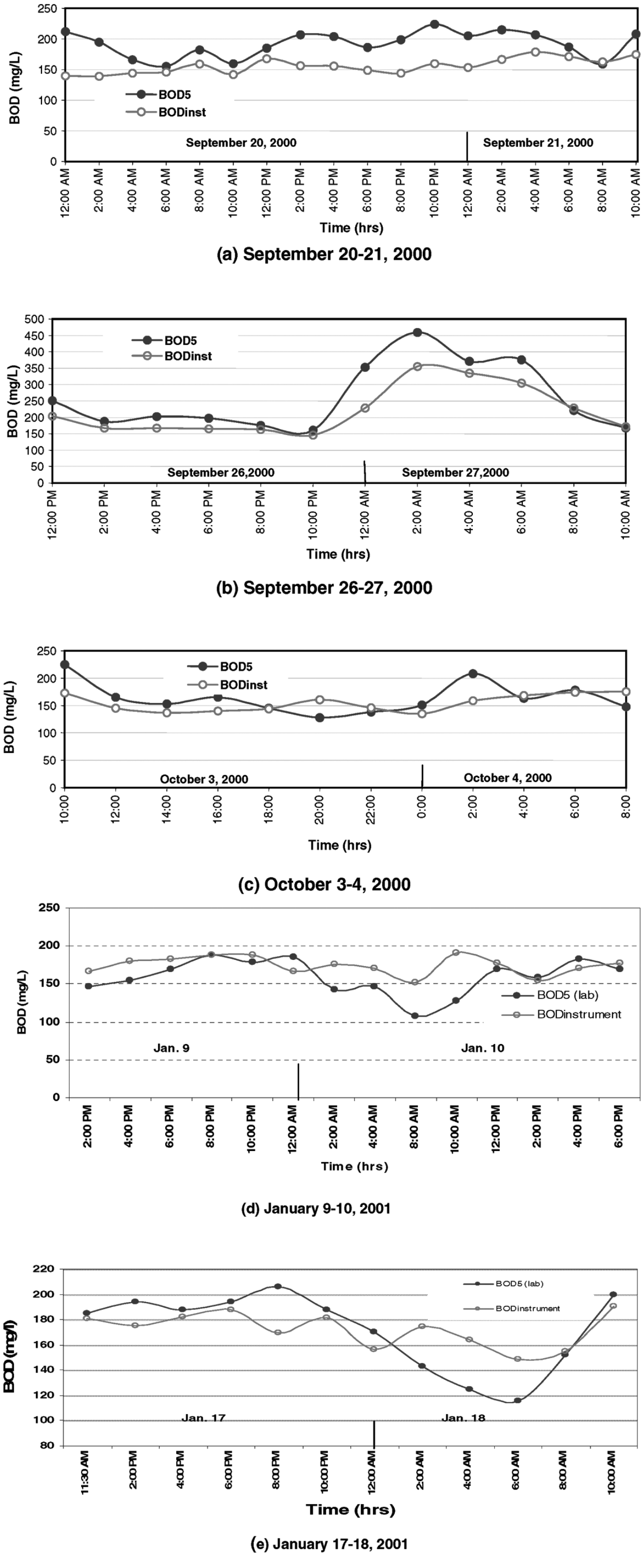

Figure 4—Field test comparison results, BOD_5 versus BOD_{inst} (instrument BOD reading).

5f, 5g, and 5k. A number of days show brief drops at approximately noon, which are times of probe membrane washings.

Response to Shock Loads. The instrument allowed LAG staff to modify process operation nearly 20 times in a period from August 30, 2000, to January 5, 2001, in response to shock-load events. Each such shock load typically lasted from approximately midnight until approximately 6 a.m. During this period of lowest flow, the plant is more vulnerable to process upsets from shock loads, causing sludge settling problems. Since late September 2000, the plant management and operation staff have been using the instrument to trigger an alarm to alert them to possible shock loads and to activate a flexible action plan that they have developed, to determine whether flow diversion and temporary storage should be carried out to damp biological load fluctuations and prevent a process upset. On November 4, 2000 (not shown), for example, the flow was reduced from the normal daytime rate of approximately 700 m^3/d (20 mgd) to approximately 49 205 m^3/d (13 mgd).

Figures 5a through 5l clearly show that the shock loads were not isolated cases, and the time pattern consistency suggested a single source. These results helped the Bureau of Sanitation's Industrial Wastes Management Division staff in determining the source of the organic load, by cross-referencing the laboratory results to their permit database. They found that the source of the shock loads was **a** pharmaceutical plant located not far from LAG.

Comparison with 24-Hour Composite 5-Day Biochemical Oxygen Demand Averages During Shock Loads. Figure 6 uses two approaches to averaging the measurements to damp out short-term fluctuations and thereby check for overall biases in the data recorded during shock loads. Because 24-hour composite samples of the plant influent are routinely obtained for BOD_5 testing as part of monitoring plant compliance with its NPDES permit, these data were selected for the days when the BIOX-1010 indicated a shock load. They are plotted in the figure in the line marked "BOD_5 (24-hr composite average)". The BIOX data were recorded every 2 minutes, so they were averaged for 1 day to be analogous to the composite sample used for the determination of BOD_5 using *Standard Methods* (APHA et al., 1992). These are plotted in the line marked "BOD_{inst} (24-hr average)". The horizontal scale is labeled with the dates of the respective points, because plotting the points equally spaced for ease of viewing obscures the actual time clustering. Evidently, the two types of averages (i.e., averages computed for the online BOD data and the standard BOD_5 data obtained at 20°C) generally agreed well and occasionally were almost identical. Furthermore, the plot does not clearly indicate any long-term bias in the BIOX results.

Statistical Analysis. Although these results do not quite live up to the near-perfect agreement between online BOD and BOD_5 reported by Riegler (1984, 1987), the distribution of these disagreements indicates that the instrument readings are estimates of true BOD values that are as good as BOD_5. This follows from two considerations. First, the results of the BOD_5 test inherently have a substantial degree of uncertainty; the best available efforts to reproduce a given BOD_5 reading from a sample of wastewater produce results that are distributed with a standard deviation of 15% (Standard Method 5210B; APHA et al., 1992), and the experience of the laboratories of the Los Angeles Bureau of Sanitation has been that variability within one laboratory is more commonly approximately 20% and between laboratories is approximately 25%. Second, a further plausible inference is that any other method that consistently produces results that agree with corresponding BOD_5 measurements to within a standard deviation of 15 to 25% is as good an estimate of true BOD as BOD_5. The distribution of the differences between corresponding BOD_5 and BIOX measurements does indicate a standard deviation of approximately 15%, with only three readings on January 10 (or approximately 5% of the 67

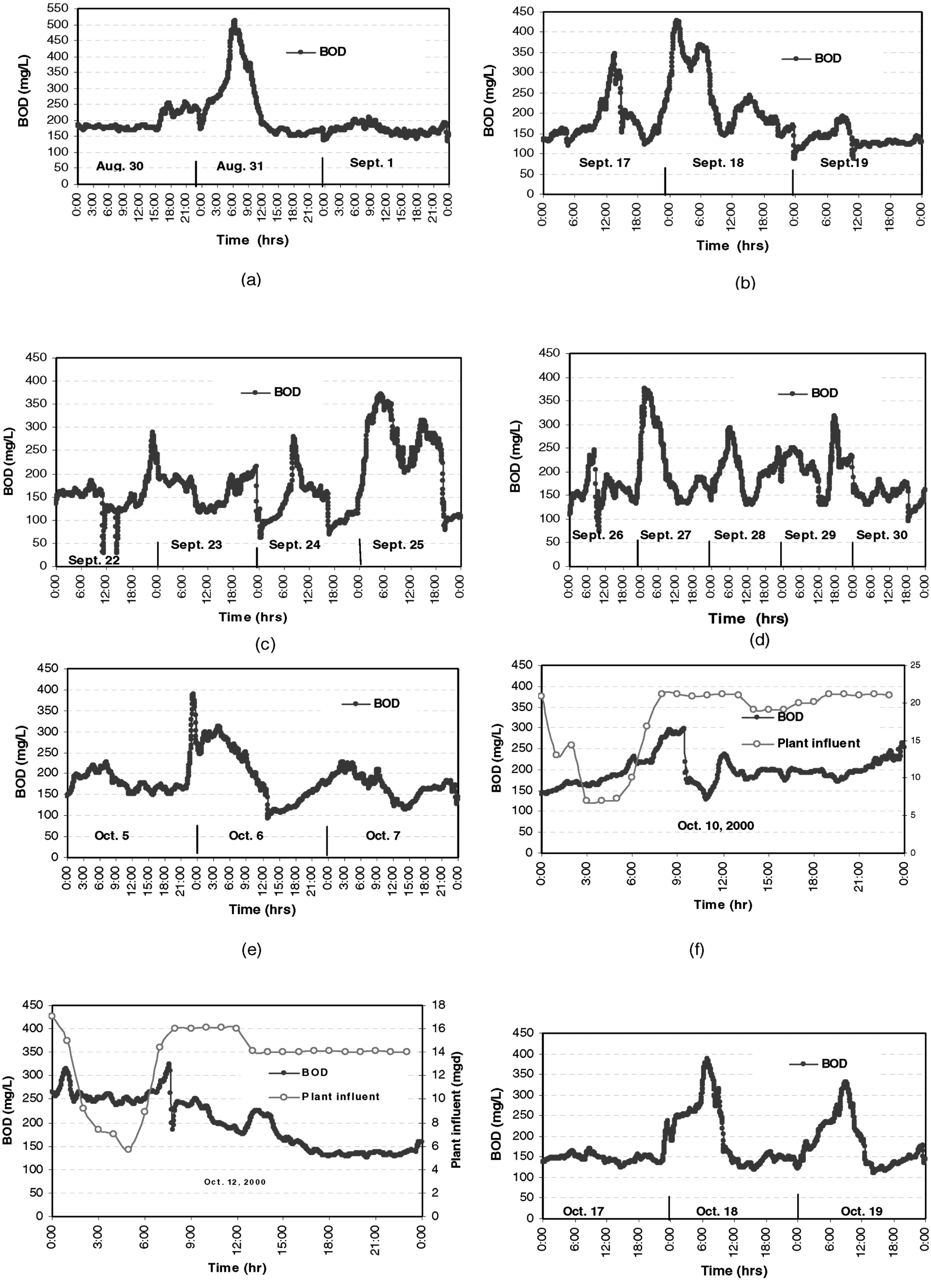

Figure 5—Detection of shock loadings in primary effluent.

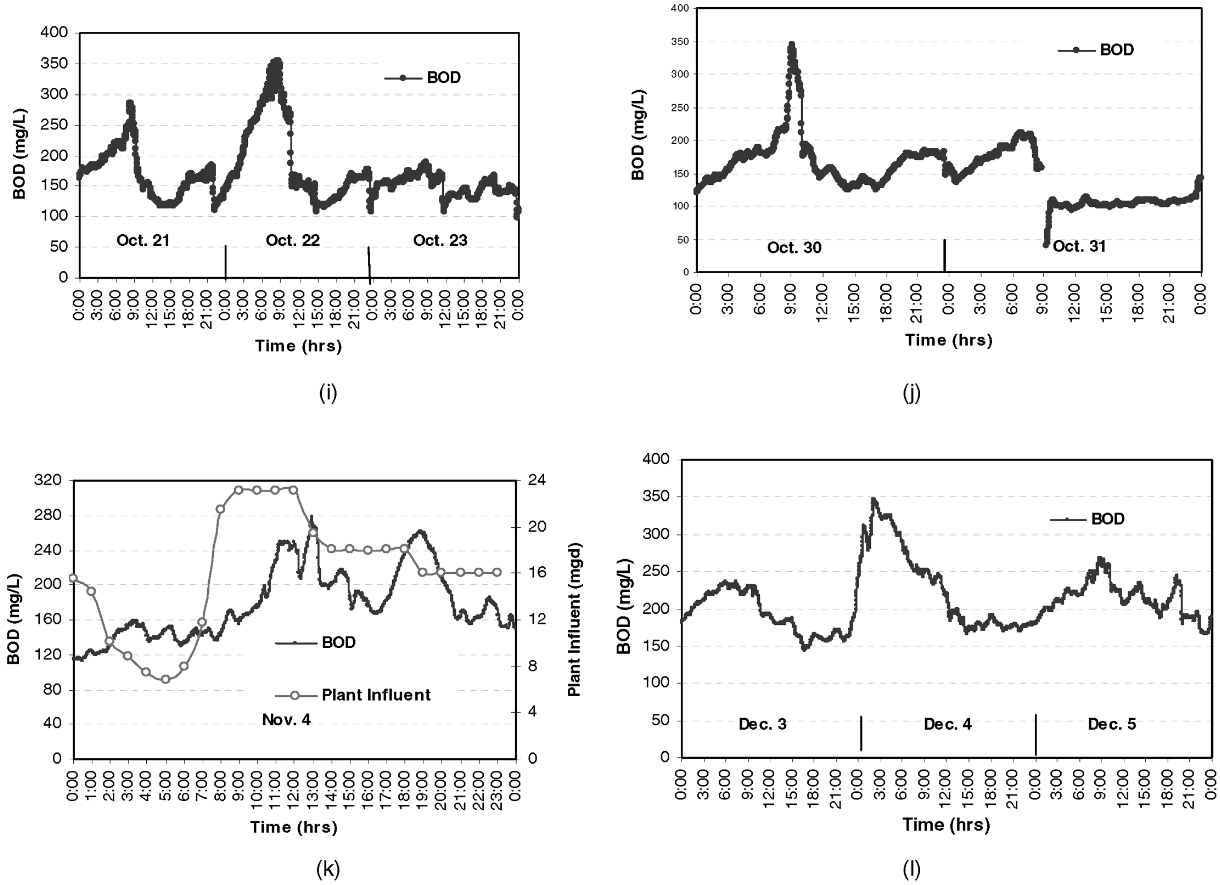

Figure 5—(Continued)

measurements in Figures 4a to 4e) disagreeing by significantly more than two standard deviations, or 30%. Although this fraction may seem high on initial consideration, the three values are consecutive samples from one event and hence are not statistically independent. Moreover, these three cases are probable overestimates of low BOD values—not underestimates of high ones—and hence are not

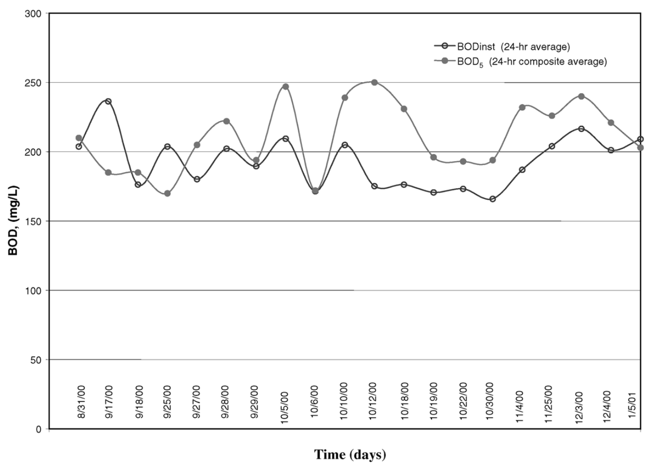

Figure 6—Comparison of daily BOD averages for shock loadings for primary effluent (BOD_{inst} = instrument BOD reading).

evidence of a risk of failing to detect a shock load. Because Figure 4b shows that both measurement methods agree reasonably well on the magnitude of the shock load and very well on the eight-hour duration, this is strong evidence that the BIOX-1010 can be used for process control.

Additional evidence for the quality of the results is provided by the mean percentage deviations shown in Table 1. These means are computed by evaluating the percentage deviation between each BOD_5 result and the corresponding online BOD reading and computing the mean of the percentage deviations for each period. Only one of the averages exceeds 15% in absolute value, with another almost exactly at 15%. The January 9 to 10 average is determined mainly by the previously mentioned three times of large deviations, and the September 20 to 21 average results primarily from one period of consistently low readings from the instrument.

These and the rest of the deviations show that the instrument readings tended to be below BOD_5 in September and above BOD_5 in January. Part of the rise may result from increasing L_k from 2.5 to 2.65 on November 22. It is also possible that enough drift occurred in the instrument response after the probe cap was changed on October 14, to account for part of these observations, because this behavior looks like a slower version of the behavior observed before the frequent spray cleanings were programmed for the dissolved oxygen probe membrane. If so, membrane replacement would restore the behavior observed in September, except with the improved accuracy expected from the revised L_k.

Table 1—Percentage deviations of BOD_{inst} from BOD_5—mean values for each period from Figure 4.

Date	Mean % deviation of BIOX-1010 from BOD_5
September 20 to 21, 2000	18
September 26 to 27, 2000	13
October 3 to 4, 2000	4
January 9 to 10, 2001	−12
January 17 to 18, 2001	−3

Table 2 presents the shock-load-event data plotted in Figure 6, with the percentage deviations of the BIOX averages from the BOD_5 values of the 24-hour composite samples. Although each of these composite samples has the effect of averaging the BOD values that occurred during the day, each daily BOD_5 value is a single measurement subject to the 15% standard deviation. Hence, because normally distributed random variables are within one standard deviation of the mean 68% of the time and outside 32%, the 6 days (out of 20) for which the percentage deviation is 15% or more are what would be expected. Likewise, 95% of the data would be less than 2 standard deviations away, and, indeed, all but one of the percentages in Table 2 are less than 30%.

The one aspect of this table not expected from the normal distribution is the preponderance of negative values, representing instrument values below the BOD_5 values. This is consistent with the September and October values in Table 1, supporting the hypothesis that L_k had been set a few percent points below its optimum value. The results show the value of making this kind of comparison, if high accuracy from the instrument is important, because this comparison is more stringent than the one made during the manufacturer's recommended test for correcting L_k.

Conclusions

The following are our main conclusions:

(1) The BIOX-1010 has given data that agree well with BOD_5, allowing for the 15% standard deviation of BOD_5 described in *Standard Method* 5210B (APHA et al., 1992) and the larger standard deviations of the Los Angeles Bureau of Sanitation's laboratories. Averages of the machine readings during shock loads generally agree well with the BOD_5 values for the corresponding 24-hour composite samples.

(2) Both the application to process control and greater insight to the conditions to which the plant must respond are benefits of the speed of the instrument (1000 to 2000 times faster than BOD_5) and its ability to produce detailed records of intraday fluctuations of BOD.

(3) The equipment has picked up many shock loads from industrial waste.

(4) The LAG plant management and operation staff have been very satisfied with the performance and results. Since late September 2000, they have been using the instrument to trigger an alarm to alert them to possible shock loads and activate a flexible action plan that they have developed, to determine whether the flow to the plant should be reduced to prevent a process upset. Long-term action plans are under development.

(5) The Industrial Waste Management Division has found this instrument to be very helpful, because it assisted them in identifying an industrial waste discharger that was greatly exceeding its permit for discharges to the waste stream.

Table 2—Percentage deviations of BOD_{inst} from BOD_5—average values for shock loads from Figure 5.

Date	BIOX-1010 average (mg/L)	BOD_5 24-hour composite average (mg/L)	Percentage deviation of BIOX-1010 from BOD_5
8/31/2000	204	210	3
9/17/2000	236	185	−28
9/18/2000	176	185	5
9/25/2000	204	170	−20
9/27/2000	180	205	12
9/28/2000	202	222	9
9/29/2000	190	194	2
10/5/2000	209	247	15
10/6/2000	171	172	0.3
10/10/2000	205	239	14
10/12/2000	175	250	30
10/18/2000	176	231	24
10/19/2000	171	196	13
10/22/2000	173	193	10
10/30/2000	166	194	14
11/4/2000	187	232	19
11/25/2000	204	226	10
12/3/2000	217	240	10
12/4/2000	201	221	9
1/5/2001	209	203	−3

We conclude that the BIOX-1010 has proven to provide acceptable BOD values for shock-load detection and to observe the diurnal BOD strength patterns for process control. The results, to date, are highly satisfactory and appear superior to competing devices and tests.

In short, the BIOX-1010 online BOD monitor works for LAG, and we believe that similar facilities with trained operators also can benefit from our experience, to operate their respective plants more efficiently.

Credits

The authors express their appreciation for the financial and technical support provided by ISCO-STIP Inc. (Lincoln, Nebraska) and by the Applied Research and the Los Angeles Glendale Water Reclamation Plant of the City of Los Angeles Bureau of Sanitation (California).

Submitted for publication March 24, 2005; revised manuscript submitted March 23, 2007; accepted for publication May 21, 2007.

The deadline to submit Discussions of this paper is July 15, 2008.

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